WHAT IS CLAIMED IS:

1. A motor-generator apparatus for a vehicle, controlled for selectively operating in an electric motor mode to perform starting of an engine of said vehicle and in an electric generator mode for generating electric power while said vehicle is running, comprising:

a field winding type of synchronous machine having a field winding,

an AC-to-DC and DC-to-AC power converter for supplying an AC armature current to an armature winding of said synchronous machine during operation in said electric motor mode,

a field current supply circuit for supplying a field current to said field winding of said synchronous machine, to produce a field winding magnetic flux, and

a control circuit for controlling said AC-to-DC and DC-to-AC power converter and said field winding circuit;

wherein while said engine starting is being performed, said AC-to-DC and DC-to-AC power converter supplies to said armature winding said armature current as a current having a component which forms a magnetic flux in the same direction as that of said field winding magnetic flux.

2. A motor-generator apparatus as claimed in claim 1, wherein during an initial period of an engine start-up

interval, said AC-to-DC and DC-to-AC power converter supplies to said armature winding said armature current having a component which forms a magnetic flux in the same direction as that of said field winding magnetic flux, and thereafter operates to set the phase of said armature current such as to enhance the generation of torque by said synchronous machine.

3. A motor-generator apparatus as claimed in claim 1, wherein when said engine is being started, prior to current being supplied to said field winding, said armature winding is supplied with an armature current such that an armature current-induced magnetic flux is formed which is oriented in approximately the same angular direction and located in approximately the same position as said field winding magnetic flux.

4. A motor-generator apparatus as claimed in claim 1, wherein said synchronous machine comprises:

a rotor core of cylindrical configuration which is mounted to be freely rotatable within a housing, with a fixed gap between said rotor core and an inner peripheral face of a stator which is fixedly attached to an inner peripheral face of said housing,

permanent magnets fixedly mounted on said rotor core, to form field magnetic poles at the outer periphery of said rotor core,

a yoke formed of a magnetically permeable material, disposed at a radially inward side of said rotor core, for providing a magnetic path for the magnetic fields of said rotor core and said permanent magnets, and also to provide a magnetic path for said field winding magnetic flux.

5. A motor-generator apparatus for a vehicle, controlled for selectively operating in an electric motor mode for performing starting of an engine of said vehicle and in an electric generator mode for generating electric power while said vehicle is running, comprising:

a synchronous machine having a rotor with a rotor core thereof having a field winding wound thereon,

an AC-to-DC and DC-to-AC power converter for receiving electric power from an armature winding of said synchronous machine and supplying electric power to said armature winding,

a field current supply circuit for performing switching control of a field current which flows in said field winding, and

a control circuit for controlling said AC-to-DC and DC-to-AC power converter and said field current supply circuit;

wherein designating a maximum allowable temperature for said rotor as Tmax, a maximum temperature that will be attained by the rotor during electric power generation operation as Tgmax, and a thermal capacity of the rotor as Q, a time interval for which current is passed through said field current during an engine starting operation as T, the resistance of said field winding as r, and the field current that is supplied generation of electric power as i, said control circuit is configured to limit said field current during generation of electric power by said synchronous machine to a value such that $(Tgmax + (i^2 . r . t)/Q)$ is lower than the temperature value Tmax.

6. The vehicle motor-generator apparatus as claimed in claim 5, wherein designating a maximum value of said field current that is supplied during an engine starting operation as imax, said control circuit is configured to limit said field current during generation of electric power by said synchronous machine to a value such that

(Tgmax + ($imax^2$. r . t)/Q) is lower than said temperature value Tmax by an amount which is within the range 10° Centigrade to 40° Centigrade.

7. The vehicle motor-generator apparatus as claimed in claim 5, wherein said control circuit is configured to derive an electrical quantity relating to an average value of said field current and an average value of said armature current during a predetermined time interval which extends up to the commencement of an engine starting operation effected by said motor-generator apparatus, and to limit at least one of said field current and said armature current to a value that is determined based upon said electrical quantity, during an electric power generation operation performed by said motor-generator apparatus.

8. The vehicle motor-generator apparatus as claimed in claim 5, wherein said control circuit is configured to derive an electrical quantity relating to ambient temperature, and to control said field current during an electric power generation operation or during an engine starting operation, to a value which is based upon said electrical quantity.

9. A motor-generator apparatus for a vehicle, controlled for selectively operating in an electric motor mode for performing starting of an engine of said vehicle and in an electric generator mode for generating electric power while said vehicle is running, comprising:

a synchronous machine having a rotor with a rotor core thereof having a field winding wound thereon,

an AC-to-DC and DC-to-AC power converter for receiving electric power from an armature winding of said synchronous machine and supplying electric power to said armature winding,

a field current supply circuit for performing switching control of a field current which flows in said field winding, and

a control circuit for controlling said AC-to-DC and DC-to-AC power converter and said field current supply circuit;

wherein said control circuit functions during an engine starting operation effected by said motor-generator apparatus to control said field current and said armature current such as to produce a magnetic saturation condition of a magnetic circuit which passes through said rotor core, and to control the value of a field magnetic force Ff to a higher value than an armature magnetic force Fa, where said field magnetic force Ff is determined as the product of

said field current by a number of turns of said field winding and said armature magnetic force Fa is determined as the product of said armature current by a number of turns of said armature winding.

10. A motor-generator apparatus for a vehicle, controlled for selectively operating in an electric motor mode for performing starting of an engine of said vehicle and in an electric generator mode for generating electric power while said vehicle is running, comprising:

a synchronous machine having a rotor with a rotor core thereof having a field winding wound thereon,

an AC-to-DC and DC-to-AC power converter for receiving electric power from an armature winding of said synchronous machine and supplying electric power to said armature winding,

a field current supply circuit for performing switching control of a field current which flows in said field winding, and

a control circuit for controlling said AC-to-DC and DC-to-AC power converter and said field current supply circuit;

wherein said rotor comprises at least one layer of thermally conductive film, disposed between layers of said field winding, with said layer(s) of thermally conductive

film extending along a direction perpendicular to a winding direction of said field winding and being disposed in contact with said rotor core.

11. A motor-generator apparatus for a vehicle, controlled for selectively operating in an electric motor mode for performing starting of an engine of said vehicle and in an electric generator mode for generating electric power while said vehicle is running, comprising:

a synchronous machine having a rotor with a rotor core thereof having a field winding wound thereon,

an AC-to-DC and DC-to-AC power converter for receiving electric power from an armature winding of said synchronous machine and supplying electric power to said armature winding,

a field current supply circuit for performing switching control of a field current which flows in said field winding, and

a control circuit for controlling said AC-to-DC and DC-to-AC power converter and said field current supply circuit;

wherein said control circuit is configured such that a predetermined initial period of an engine starting interval, said control circuit supplies said field current to said field winding with a large value of duty ratio, and

of duty ratio until completion of said engine starting interval.

12. The motor-generator apparatus as claimed in claim 11, wherein said control circuit performs repetitive switching control of the level of said field current, and wherein said control circuit continuously supplies said field current with a duty ratio of 100% for said switching control until completion of an initial compression stroke of said engine.

13. A motor-generator apparatus for a vehicle, selectively operable in an electric motor mode and in an electric power generating mode, comprising:

a multi-phase field winding type of synchronous machine having a housing, a stator core which is fixedly attached within said housing, an armature winding formed of a plurality of phase windings wound on said stator core, a field winding for producing current-induced field magnets which link with said phase windings, and a rotor-side iron core portion within a rotor core, said rotor core having magnetic poles formed therein by said current-induced field magnets in a circumferential face which is positioned opposite said stator core,

AC-to-DC and DC-to-AC power converter means for applying to said stator winding AC phase voltages which respectively differ in phase, and for rectifying AC electrical power produced from said armature winding, and

control circuit means for supplying phase-advanced currents, which differ in phase by a predetermined phase angle from said AC phase voltages, to said armature winding from said AC-to-DC and DC-to-AC power converter, for thereby operating said synchronous machine as an electric generator;

wherein said rotor-side iron core portion is configured to have a smaller value of magnetic reluctance in a direction that is at right angles to a direction of said magnetic flux of said current-induced field magnetis than a value of magnetic reluctance in said direction of said flux of the current-induced field magnets.

14. The apparatus as claimed in claim 13, wherein:

said field winding is wound on a field core which forms part of said rotor-side iron core portion and is fixedly attached to said housing, separated by a fixed air gap from said rotor core, and

said rotor core has attached thereto a plurality of permanent magnets for forming a plurality of permanent

magnet-induced field magnets whose magnetic flux links with said phase windings of said field winding.

15. The apparatus as claimed in claim 14, wherein said rotor core is formed of a plurality of plates of soft magnetic material stacked along an axial direction of said rotor core and having magnet accommodation apertures formed therein to accommodate said permanent magnets.

16. A motor-generator apparatus for a vehicle, operable for selective performing starting of an engine of said vehicle and generating electric power while said vehicle is running, having a synchronous type of generator-motor comprising:

a housing,

a stator core attached to an inner peripheral face of said housing,

an armature winding formed on said stator core,

a rotor core of cylindrical form, mounted for rotation within said housing with a predetermined gap between said rotor core and an inner periphery of said stator core,

an even number of permanent magnets, respectively retained in an even number of magnet accommodation apertures each formed extending along an axial direction in said stator core, with an even number of field poles

produced by said permanent magnets being arranged successively alternating in polarity around the outer circumference of said rotor core,

magnetic shunt members inserted in respective magnetic shunt member accommodation apertures extending along said axial direction of the rotor core, for shunting magnetic fields produced by said permanent magnets,

a field winding disposed at the inner peripheral face of said rotor core, for producing a magnetic flux within said magnetic shunt members along the axial direction, and

a yoke member, disposed at the inner periphery of said rotor core, to form a flow path for the magnetic flux produced by said field winding, in conjunction with said rotor core and said magnetic shunt members;

wherein each of said permanent magnets has a portion thereof disposed radially inward from said magnetic shunt members, and said rotor core has a magnetic path which extends from a region at the outer periphery of said rotor core through a region disposed between two circumferentially adjacent ones of said permanent magnets and to a region which is located radially inward from said permanent magnets.

17. A vehicle motor-generator apparatus as claimed in claim 16, wherein said magnet accommodation apertures are

each of arc shape as seen in cross-section in a plane which is at right angles to a rotational axis of said rotor core, with end portions of each of said magnet accommodation apertures extending to the outer periphery of said rotor core and each magnet accommodation aperture having a circumferentially central portion which is disposed radially inward from said end portions thereof, and wherein said permanent magnets are mounted substantially in a depth direction of said magnet accommodation apertures, with a circumferentially central portion of each of said magnet accommodation apertures formed with a concave shape in a circumferential face of said rotor core.

18. A vehicle motor-generator apparatus as claimed in claim 17, wherein respective circumferentially central points of said permanent magnets substantially coincide with circumferentially central points of said magnetic shunt members.

19. A vehicle motor-generator apparatus as claimed in claim 16, wherein the outer periphery of said rotor core has pairs of pole protrusion members, each formed between a pair of slits extending along the axial direction of said rotor core and each disposed between an arbitrary pair of said field poles, with a plurality of said pole protrusion

members circumferentially disposed at equal spacings around the periphery of said rotor core.